A Comparison of Two Methods of Analog-to-Digital Medical Video Conversion

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The purpose of this study was to compare 2 methods of analog-to-digital video conversion in anticipation of improving, refining, and standardizing digital video production for medical education, diagnosis support, and telemedicine. A video workstation was devised containing 2 analog-to-digital video conversion systems: a digital video media converter with fire wire card and a video capture card. A procedure for final digital video production was created that used equivalent compression, pixel resolution, frame rate, and data rate for both systems. A subjective test was performed in which 12 archived analog videotapes, consisting of magnetic resonance angiograms, ultrasounds, neurosurgeries, and telemedicine applications, were converted digitally using the 2 methods. Randomized side by side video comparisons were analyzed and rated by subjective quality. An objective test was performed by videotaping a gray-scale test pattern off a computer monitor, digitally converting it by the 2 methods, and comparing the gray-scale values to the original pattern. There was no significant difference in overall video quality ($P = .31$) or gray-scale reproduction using the 2 methods of analog-to-digital conversion. When performing simple analog-to-digital video conversion, a video capture card is equal in quality and costs less than a digital video (DV) media converter or fire wire card. If a digital video camera is available for use, then a DV media converter or fire wire card is more advantageous because it enables full operation of the digital video camera.

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THE PROCESS of analog-to-digital video conversion and final digital video preparation needs to be refined and standardized to improve digital video quality for medical education, diagnosis support, and telemedicine. To date, medically related digital videos have not played a key role in these computer-based applications because of the impracticality of playback on a standard computer system. A standardized method that retains high video quality with an easily managed data rate is needed greatly in the medical community.

MEDICAL EDUCATION

The personal computer (PC) is playing an ever expanding role in medical education.¹ Incorpora-

tion of video² and animation³ has enhanced the quality of medical education software. The instructional effectiveness of a multimedia medical textbook has been shown to be greater than that of a standard medical lecture.⁴ Recent developments in radiology education have produced a need to acquire radiological videos in digital form for use on PCs. Computer-based radiology learning tools, published on CD-ROM or over the internet, can make use of videos to strengthen teaching points.⁵ Unfortunately, many of the most valuable teaching videos are sitting around physician's offices as archived analog videotapes. These videos must be digitally converted so they can be used in multimedia presentations, on CD-ROM, or over the Worldwide Web. However, if the conversion process eliminates the diagnostic quality or the data rate is too high for playback, digital video becomes impractical.

DIAGNOSIS SUPPORT

For radiologists, the image or video is the basic carrier of information. When making a diagnosis, radiologists frequently access image collections for reference. The most commonly used source of radiological reference images are atlases and teaching files, whether film, slide, or laser disk based.⁶ Computer-based applications such as electronic textbooks, knowledge-based systems, and databases constitute a new source for image reference.⁷⁻¹¹ However, videos have not yet played a key role in these computer-based applications because of their impracticality. Diagnosis support could be

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dramatically improved if digital videos could be incorporated into these computer-based references.

TELEMEDICINE

Providing quality health care can be a challenge in some rural and urban areas in which health care personnel are scarce and access to modern technology is lacking. Recent advances in computer networking and digital video technologies have enabled cost-effective transport of digitized medical imagery across a wide area network link. Thus, these images can be transmitted from a distant site to a central hospital. Moving images, videos, and patient information instead of people results in increased efficiency for hospitals and more timely diagnoses for patients in distant areas; it also increases the population readily served by a single hospital.¹² For example, a rural physician could videotape an eye or oral cavity exam, digitize the video, and send it over a network to a specialist, saving considerable time for the patient.

The advantages of digital versus analog representation are well documented.¹³ Digital transmission almost is completely unaffected by distance with extremely low error rates, as well as the ability to perform error checking. Reliable protocols can ensure an accurate transfer of digital image data over wide-area links with no loss in image quality. In contrast, an analog signal may suffer from a decrease in its signal-to-noise ratio as the transmission distance increases.¹²

In this study, the 2 methods of analog-to-digital conversion that we tested were (1) through a video capture card and (2) through a digital video (DV) media converter. To our knowledge, there have been no reports comparing these methods using radiographic, surgical, and telemedicine videos. This report details the results of our tests and provides recommendations for the overall framework of medically related digital video production.

METHODS

A video workstation was set up that consisted of a PC with 128 MB of random-access memory (Pentium II processor [266 MHz]), a computer monitor (ViewSonic P810; Walnut, CA), a video cassette recorder (Panasonic AG-5700 SVHS; Secaucus, NJ), and a television monitor (Panasonic CT-1384). A medium cost video capture card (Matrox Millennium II/Rainbow Runner Studio capture card with a video connector bracket; Dorval, Quebec, Canada) was acquired and installed in the PC. Also, a digital video media converter (Sony DVMC-DA1; Park Ridge, NJ) and fire wire card (Digital Origin Moto DV 1394 firewire adapter card; Mountain View, CA) were acquired and installed.

Table 1. Capture and Final Exportation Settings for Video Capture Card

Capture Card Settings	Capturing	Final Exporting
Resolution (in pixels)	704*480	352*240
Frame rate	30 frames/s	29.97 frames/s
Compressor	Matrox MJPEG	MPEG-1
Data rate	3000 KB/s	244 KB/s
File type	AVI	MPEG

Subsequently, 12 archived analog videotapes were obtained, consisting of 3 magnetic resonance angiograms, 3 ultrasounds, 3 neurosurgical procedures, and 3 telemedicine applications (a physical examination of an eye, throat, and skin lesion).

Video Capture Card Method

An S-video cable was connected from the VCR to the S-video-in on the video connector bracket in the PC. The analog videotape was played in the VCR and captured to the PC by the PC-VCR remote software (Matrox Graphics, Inc, Dorval, Quebec, Canada) included with the capture card using the settings shown in Table 1. The video file was then clipped in Adobe Premiere 5.1 so that associated videos would start and end on equivalent frames. The file was then exported using the same settings with which it was captured to preserve the video quality. Finally, the clipped video file was compressed with an MPEG-1 codec (Digigami MegaPeg version 1.07; San Diego, CA) with the settings seen in Table 1. Although this final compression step reduces the video image quality, this easily managed data rate was selected for comparisons because it is similar to that used in medical education and is acceptable for creating a CD-ROM. The initially captured data rate is too large for smooth playback on standard computers.

DV Media Converter

An S-video cable was connected from the VCR to the S-video-in on the DV media converter. A fire wire was then connected to the DV in/out on the DV media converter and run to the fire wire card on a Macintosh computer. The analog videotape was played in the VCR and converted digitally in the DV media converter and transferred directly through the fire wires to the fire wire card with the settings found in Table 2. The video file was then clipped in Adobe Premiere 5.1 (San Jose, CA) so that associated videos would start and end on equivalent frames. The file was then exported using the same settings with which it was captured to preserve the video quality. Finally, the clipped video file was compressed with an MPEG-1 codec (Digigami MegaPeg version 1.07) with the settings seen in Table 2.

Table 2. Capture and Final Exportation Settings for DV Media Converter

Fire Wire Card Settings	Capturing	Final Exporting
Resolution (in pixels)	704*480	352*240
Frame rate	29.97 frames/s	29.97 frames/s
Compressor	RadiusSoftDV-NTSC	MPEG-1
Data rate	3430 KB/s	244 KB/s
File type	Quick Time	MPEG

Fig 1. Side by side comparison of digital videos produced by video capture card (video 1A) and DV media converter (video 1B).

Subjective Tests

The 12 archived analog videotapes, containing radiological, neurosurgical, and telemedicine procedures, were converted to digital format using the 2 methods described above. The brightness, contrast, hue, saturation, and sharpness video settings were matched. To perform video quality comparisons, the videos were placed randomly side by side in pairs into a Microsoft PowerPoint presentation (Fig 1) and saved on CD-ROM. The evaluators consisted of 3 neuroradiologists, 1 neuroradiology fellow, 1 neurosurgeon, and 2 medical students. Evaluators were asked to rate each set of test videos in terms of overall subjective video quality, paying particular attention to sharpness, clarity, and smooth video playback. The rating scale ranged from +5 to -5. Positive numbers indicated that the upper video had higher quality and negative numbers indicated that the lower video had higher quality; a score of 0 indicated that the 2 videos were identical in quality.¹⁴

Objective Tests

Gray-scale response was assessed by using a Society of Motion Picture and Television Engineers (SMPTE) test pattern. The test pattern consisted of an 11-step gray-scale from 0% (white) to 100% (black) at 10% intervals. The SMPTE test pattern was videotaped with a Canon (Jamesburg, NJ) ES970 8mm Video Camcorder directly from the computer monitor. The analog video then was converted to digital format by the 2 methods described above. The brightness, contrast, hue, saturation, and sharpness capture settings were all set at 50%. A still frame was exported as a TIFF file type, and the gray-scale values were measured in each of the 11 boxes.

RESULTS

Subjective Test

The evaluations of all observers were pooled into a single data set consisting of 84 matched pairs. The mean score given by the evaluation panel was +0.14 in favor of the DV media converter, with a standard deviation of 1.14. A Wilcoxon Sign Rank test was performed on the data and produced a Wilcoxon statistic of 100.5.¹⁵ This value indicated that the evaluators detected no significant difference in overall video quality between the DV media converter and video capture card ($P = .31$).

Objective Test

Figure 2 contains a graph summarizing the objective test results. The ideal gray-scale response would be a straight line with a slope of one. However, the responses of the DV media converter and video capture card both produced nonlinear curves. Neither conversion method could achieve grayscale values at the extremes of the spectrum, showing grayscale degradation during video conversion. In general, the video capture card tended to

Fig 2. Graph compares the gray-scale curves obtained in the objective test.

produce darker images at each interval than the DV media converter, thus more closely approaching the darkest or 100% interval. However, the gray-scale response for the DV media converter was identical to the original SMPTE chart for the grayscale range of 30% to 70%. This could account for the slight, although not significant, preference for the DV media converter in the subjective test.

DISCUSSION

When performing simple analog-to-digital video conversion, a video capture card is equal in quality and costs less than a DV media converter or fire wire card. A medium-grade video capture card costs around \$350, whereas a DV media converter or fire wire card software is approximately \$850. However, if a digital video camera is available for use, then a DV media converter or fire wire card has more advantages. A fire wire card allows direct transfer of digital video information from a digital video camera to a computer without any loss of quality. A DV media converter allows viewing of digital videos on a TV monitor. High-quality digital video can be seen on a television when a digital video camera is connected to a television via the DV media converter.

Digital video production can seem difficult and complex to physicians without a technical background. To facilitate this production process, a discussion and layout of the tools and settings necessary to produce high quality digital videos for educational conferences, diagnosis support, and telemedicine has been included. An eventual standardized process of digital medical video output will produce compatible videos of the highest quality. Figure 3 provides a general scheme of digital video production, with specific details of the steps discussed below.

The data rate and file size of uncompressed digital video can overwhelm many personal computers and hard disks. Video compression is used to lower the data rate of digital video into a range that

personal computers can handle. Of the factors we analyzed, compressor selection had the greatest effect on subjective video quality. MPEG (Moving Picture Expert Group) video compression is used in many current and emerging products and works well in a wide variety of applications. MPEG is a core feature of digital video television set-top boxes, DVD players, video conferencing, internet video, and other applications. The benefit of MPEG compression over other compressors is that it is able to compress video to easily managed data rates, while maintaining video quality. What is commonly referred to as *MPEG video* actually consists primarily of 2 finalized standards, MPEG-1 and MPEG-2. MPEG-1 is used with video CDs, multimedia, and web authoring. MPEG-2 is used with DVD (digital video disk). Microsoft Windows and Macintosh systems contain a built in decompressor for MPEG. A common problem with most other compressors is that the digital videos are not able to be played on these systems, requiring additional software. The simplest thing to do in setting up a video workstation is to purchase a video capture card that has MPEG compression already built in. Although this increases the cost slightly, this automates the compression step (Fig 3) in making digital videos.

Data rate is a measurement, in kilobytes (KB) per second, of the amount of video information that must be processed each second during playback. It must be high enough to preserve maximum quality and low enough to play back smoothly. The final data rate specified depends on the purpose of the video. It must fall within the data transfer capacity of the systems of the audience. If the final video will be played back from a hard disk, the typical data transfer rate of the audience's hard disks must be determined and the data rate set accordingly. The data rate for video played from a CD-ROM depends on the speed of the drive. For example, if preparing a video file for a double-speed CD-ROM drive (300 KB per second), a data rate of about 250 KB per second might be specified to account for

Fig 3. Layout of general scheme of analog-to-digital video conversion and final digital video production.

Table 3. Ideal Data Rates for Specific Applications

Application	Data Rate
Hard Drive	500 KB/s
Video CD*2	250 KB/s
Video CD	125 KB/s
Local network	100 KB/s
ISDN	8 KB/s
Modem	4 KB/s

both the data rate of the drive and the system overhead required to move the data. For streaming video over the Worldwide Web, the data rate should account for real-world performance at the target data rate because factors such as data volume and line quality often prevent telephone-based internet connections from consistently achieving their stated data rate. To simplify matters, Table 3 shows recommended data rates for certain specific applications. This table was reproduced from the MPEG-1 codec (Digigami MegaPeg version 1.07) software recommendations.

Resolution is the density of pixels per inch that make up an image. We used a pixel resolution of 352*240 because MPEG-1 has been optimized to work at this resolution. However, in general, if not using MPEG-1 compression it is best to keep the same proportions at which the video was captured to avoid degradation of image quality caused by

resampling. Digital video cameras capture at 720*480 and certain capture cards capture at other pixel resolutions. If resampling is necessary, it is important to keep the aspect ratio constant to avoid distortion of the images.

We found no significant difference in overall video quality ($P = .31$) or gray-scale reproduction using the 2 methods of analog-to-digital conversion. In performing simple analog-to-digital video conversion, a video capture card is equal in quality and costs less than a DV media converter or fire wire card. However, if a digital video camera is available for use, then a DV media converter or fire wire card is more advantageous because it enables full operation of the digital video camera. In addition, we learned about and discussed the mechanics of producing final digital videos, which may be useful for others who are attempting to use medical digital videos in medical education, diagnosis support, and telemedicine. Quantitative data on the reduction in image quality by the analog-to-digital conversion process was not generated and beyond the scope of this study. However, this would be an interesting topic for additional research. We hope this study and these recommendations will help improve the utilization of digital videos in medicine, both for educational and clinical applications.

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